PUBLIC TRANSPORT CORPORATION

MELBOURNE

INSTALLATION MANUAL

UM71 TRACK CIRCUIT

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1. PURPOSE OF THE DOCUMENT

The purpose of this document is, within the context of the PTC network, to define the installation of the UM 71 type track circuit:

- gauge track, 1,603 m
- 53Kg/m rails
- d.c. 1500 V electrified tracks.

This document contains:

- general considerations on the UM 71 track circuit,
- the principle of operation of the various items making up the track circuit,
- a physical description of these items,
- layout rules (connections, track circuit length, protection against atmospheric voltage surges, etc.),
- installation of field equipment along the track as well as in signal boxes and equipment rooms,
- settings to be made and commissioning of track circuits.

2. GENERAL

2.1 Purpose of the UM 71 track circuit

The UM 71 track circuit allows safe detection of the presence of a train on the track section on which it is installed.

The "unoccupied" or "occupied" status of the track circuit is the basic data of the signaling logic. This data conditions:
- train spacing functions,
- route control,
- point control and interlocking,
- train follow-up,
- etc.

The UM 71 track circuit can be used :
- on d.c. electrified tracks,
- on a.c. electrified tracks,
- on non-electrified tracks.

As regards electrified tracks, the traction current return circuit must be the bi-rail type.

2.2 Configurations of the UM 71 track circuit (Appendix 1)

The UM 71 track circuit can be set up for end of section transmission or intermediate transmission.

In end of section transmission configuration, a termination is used by the track circuit as transmission point, as a rule the downstream end, with the upstream termination making up the reception point (Fig. 1).

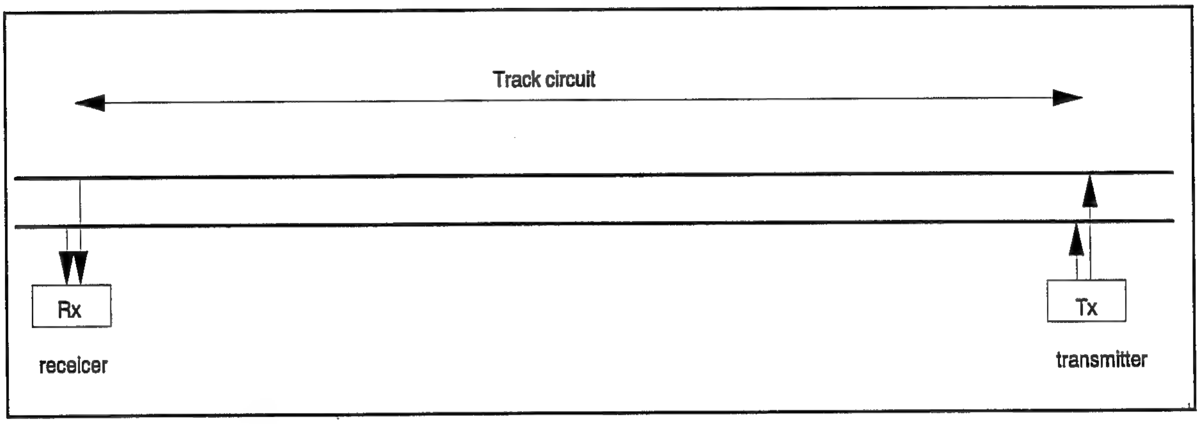


Figure 1 - End of section transmission TC

In intermediate transmission configuration transmission is provided at the centre of the track circuit. A receiver is installed at each end of the track circuit.

The data delivered by both elementary receivers are generally summed (Fig. 2), and this is particularly important with compensated track circuits.

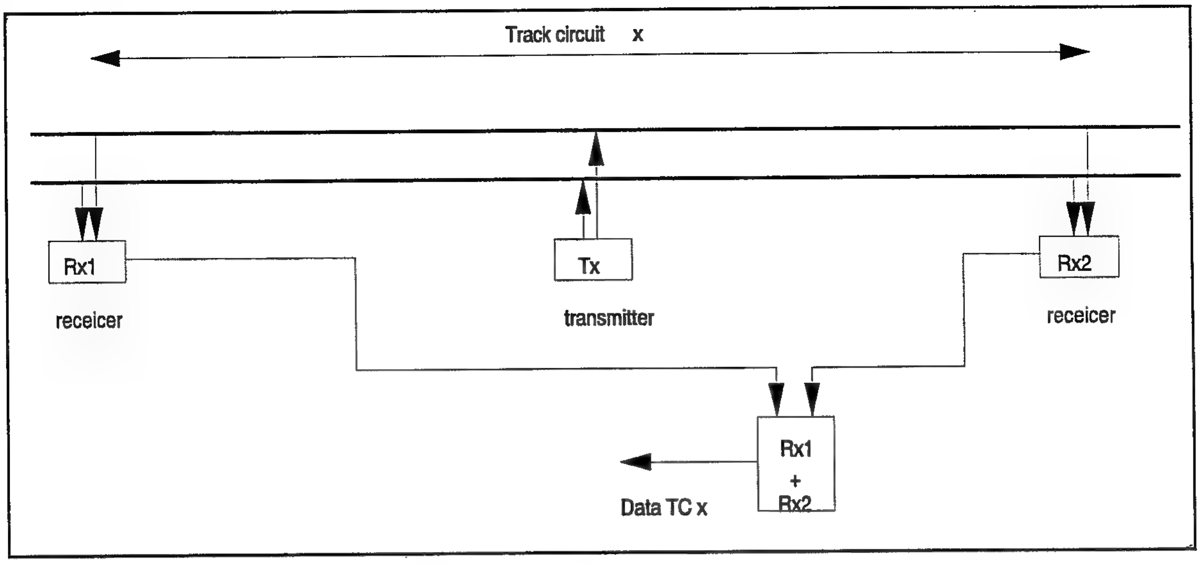


Figure 2 - Intermediate transmission track circuit

The track circuit can operate with significant asymmetry between elementary branches.

2.3 Track circuit termination (Appendix 2)

In conventional open-line installations, the UM 71 track circuit is limited at each end by an electrical separation joint (ESJ).

The purpose of the ESJ is:

- to provide continuity of the traction return circuit without creating a mechanical discontinuity of the rail (insulated rail joints); this makes it compatible with the laying of long welded rails.

- to inhibit signalling current propagation beyond the track circuit limits.

At the boundary with different technology track circuits (e.g. ITE or 50 Hz or d.c.), the UM 71 track circuit must be limited by insulated rail joints (IRJ) termination : i.e. one joint on each stretch of rail.

Traction current return continuity is provided at insulated joint crossing by track inductors.

2.4 Intermediate data collector - IDC (Appendix 3)

The Intermediate Data Collector makes up an auxiliary receiver which can be installed within the track circuit limits.

Important:

The intermediate data collector cannot be used in compensed track.

It exists two types of intermediate data collector. Each type applies in different use:
- intermediate data collector in voltage , IP (Information Point)
- intermediate data collector in current, PPD (Pin Point Détector)

2.4.1 Intermediate data collector in voltage - IP

This configuration is not used in the PTC context.

As a rule, the Intermediate Data Collector associated with an intermediate transmission track circuit allows level crossing release functions, providing barrier reopening or enabling road signs after crossing of a train.

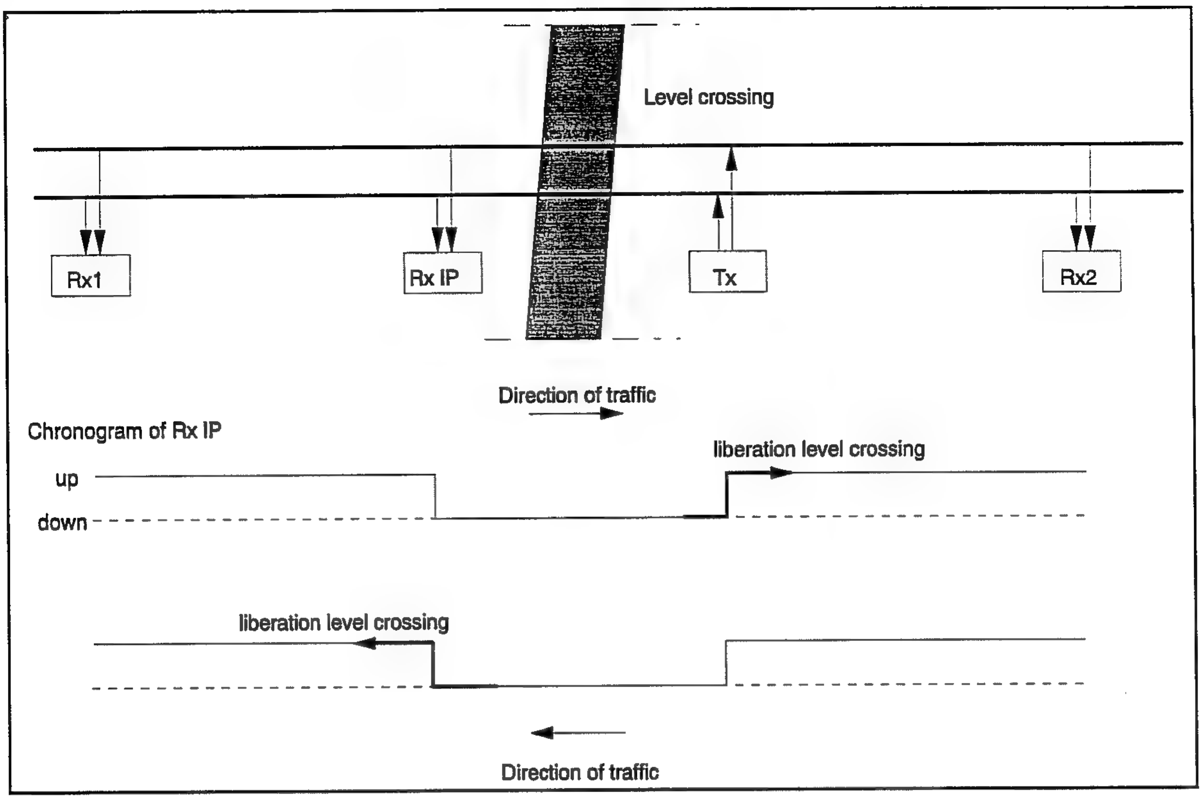


Figure 3 - IP (level crossing)

The track section included between the transmitter Tx and the Intermediate Data Collector IP makes up an self-operated track circuit (Fig. 3). The IP shunt point is before the IP location. None signal can be associated to the IP because the signal is switched off before the IP has been passed throught. The IP is generally used to provide liberation information (i.e. Level Crossing). in this case the transmitter is located upstream of the Track Circuit.

2.4.2 Intermediate data collector in current - PPD

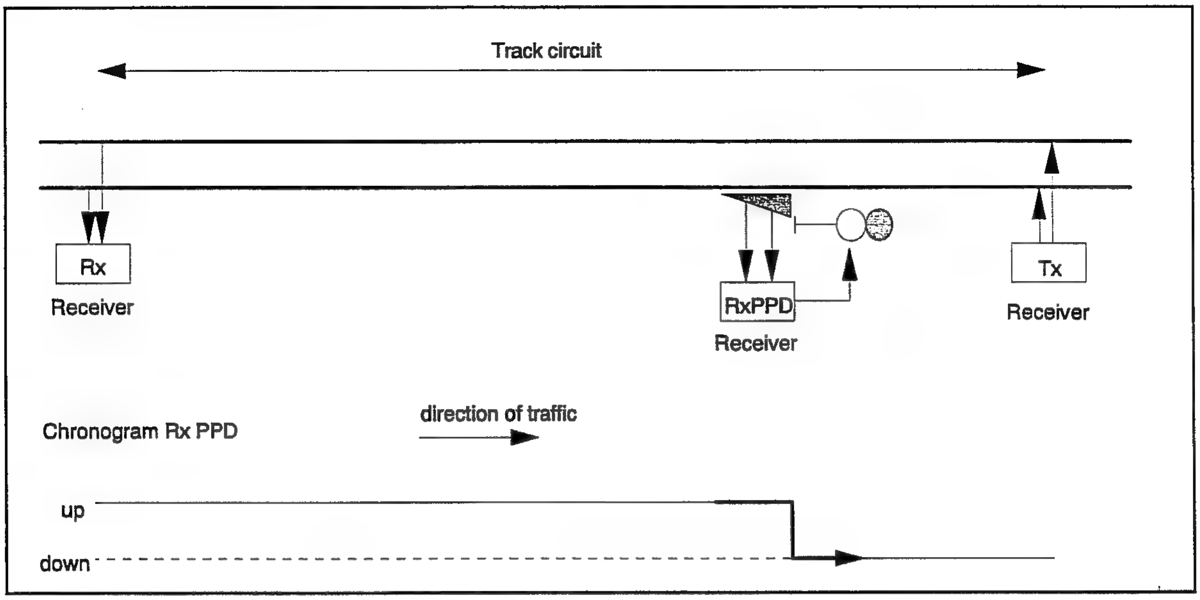


Figure 4 - PPD (Anticipated switch of sign)

Generally used for anticipated switch off signal (fig.4). For example when signs are not located close to the ESJ, but few meters upstream. This equipment can switch off the sign as soon as it has been passed throught without waiting the ESJ to be passed.

2.5 Use of the UM 71 track circuit in points (Appendix 4)

Isolation of the points and crossings must be provided per the "parallel" arrangement. Furthermore, the maximum length of the antenna connected to the main line is in principle set at 12 meters. However, greater antenna lengths can be tolerated if not exceeding 36 meters, provided polarity transfers are implemented at 12-metres intervals, from the point and crossing joints to the fouling point.

Note:
The broken rail is not detected in 36m areas.

For lengths in excess of 36 meters, an additional receiver shall be created on insulated rail joints at end of antenna; in this case, the broken rail is always detected. (See appendix 4).

3. UM71 TRACK CIRCUIT CARACTERISTICS

3.1 Design parameters

The operational characteristics of the UM71 jointless track circuits as described in this document are valid for the following conditions:

- 53Kg/m to 60Kg/m rail
- space permeability of the rail ranging from 80 to 150
- 1.603m gauge track
- wooden or concrete sleepers
- insulation between rail, equally distributed
- equally distributed propagation constant
- rail connections resistance less than 100 microohms.

3.2 Ballast resistance

The operation to the jointless track circuits developed for the PTC is ensured for a minimum values of ballast resistance of 1,5 ohm.Km.

3.3 Theoritical drop shunt

The maximum value of non inductive resistor which, when connected between the rails causes the relay to de-energise, even under the worst case is called the "theoretical limit of shunt".

For the track circuit used by PTC, a minimum value of 0.1 ohm is guaranteed, except within the tuned area.

In the tuned area, the theoretical limit of shunt varies from 0.1 to 0 ohm and there is an "overlap" of the shunt areas of the two successive track circuits with receiver/transmitter and receiver/receiver electrical joint. There is not overlap for transmitter/transmitter electrical joints.

3.4 Maximum and minimum track circuits length

The lenght of the track circuit is measured between the points connection of the air core inductor.

With a minimum value resistance ballast of 1.5 ohm.Km:

1) without compensation track

Maximum length
- End fed transmission : 650m

Minimum length
- End fed transmission : 100m

2) with compensation track

Maximum length
- End fed transmission:
  . up to 1100m

Minimum length
- End fed transmission : 600m

Maximum length of track circuits installed with Intermediate Data Collector

1) Pin Point Detector - PPD

- End fed transmission
  . without boosting unit: 250m
  . with boosting unit: 400m

2) Information Point - IP

- End fed transmission: 650m

3.5 Maximum lines length between ESJ/IRJ/PPD/IP equiments and transmitter/receiver

transmission line with ESJ/IRJ/IT :	150m
reception line with ESJ/IRJ:	150m
reception line with PPD:	100m
reception line with IP:	1000m

Cables caracteristics are presented in chapter 6

3.6 Broken rail detection

Broken rail detection is provided when the provision described in this manual are used

4. PRINCIPLE OF OPERATION

4.1 Frequency distribution (Appendix 5)

4.1.1 Frequency assignment scheme

The UM 71 track circuit operates at one of four basic carrier frequencies grouped in two pairs:

- One pair assigned to track 1:
  . V1-F1 : 1700 Hz
  . V1-F2 : 2300 Hz

- One pair assigned to track 2:
  . V2-F1 : 2000 Hz
  . V2-F2 : 2600 Hz

4.1.2 Frequency junctions

Successive track circuits, or track circuits installed on parallel tracks must operate at different frequencies.
When there are more than two parallel tracks, adjacent tracks must be assigned different frequencies, and special care should be taken when setting up equipotential links between tracks. (See paragraph 7).

Junction on electrical joint of two frequencies not belonging to the same pair is not available at this time.

Termination junction on insulated rail joints of two track circuits with the same frequency is prohibited. In this case, it is possible to use frequencies not belonging to the same pair.

4.1.3 Frequency junctions in line cables

IMPORTANT RULE

Routing of a transmission and a reception with the same frequency within one same cable is prohibited.

Circuit pairing
When wiring and installing the track circuits, circuit pairing should be observed in the line cables.

Each transmission or reception circuit shall use conductors from one same pair.

Incorrect circuit pairing results in cable transmission parameters being changed and may induce significant cross-talk levels in adjacent circuits.

4.2 Transmitter

4.2.1 UM 71 signal

The transmitter generates a power-limited sinusoidal signal, at one of the four Fo basic frequencies: 1700 Hz, 2000 Hz, 2300 Hz or 2600 Hz.

To provide protection against the various spurious signals from the track:
- 50 Hz traction current harmonics,
- currents output by chopper-equipped locomotives,

the Fo basic frequency is encoded by "shifting" (fig.1).

"Shifting" consists in switching two frequencies with a modulation depth $\Delta F = 11Hz$, i.e.:

$$F_0 + \Delta F \text{ and } F_0 - \Delta F$$

The basic frequency is thus frequency-modulated at a rate set by division by 128 of this basic frequency Fo; hence the following VLFs:
- 13.3 Hz for a transmitter at Fo = 1700 Hz
- 15.6 Hz for a transmitter at Fo = 2000 Hz
- 18.0 Hz for a transmitter at Fo = 2300 Hz
- 20.3 Hz for a transmitter at Fo = 2600 Hz

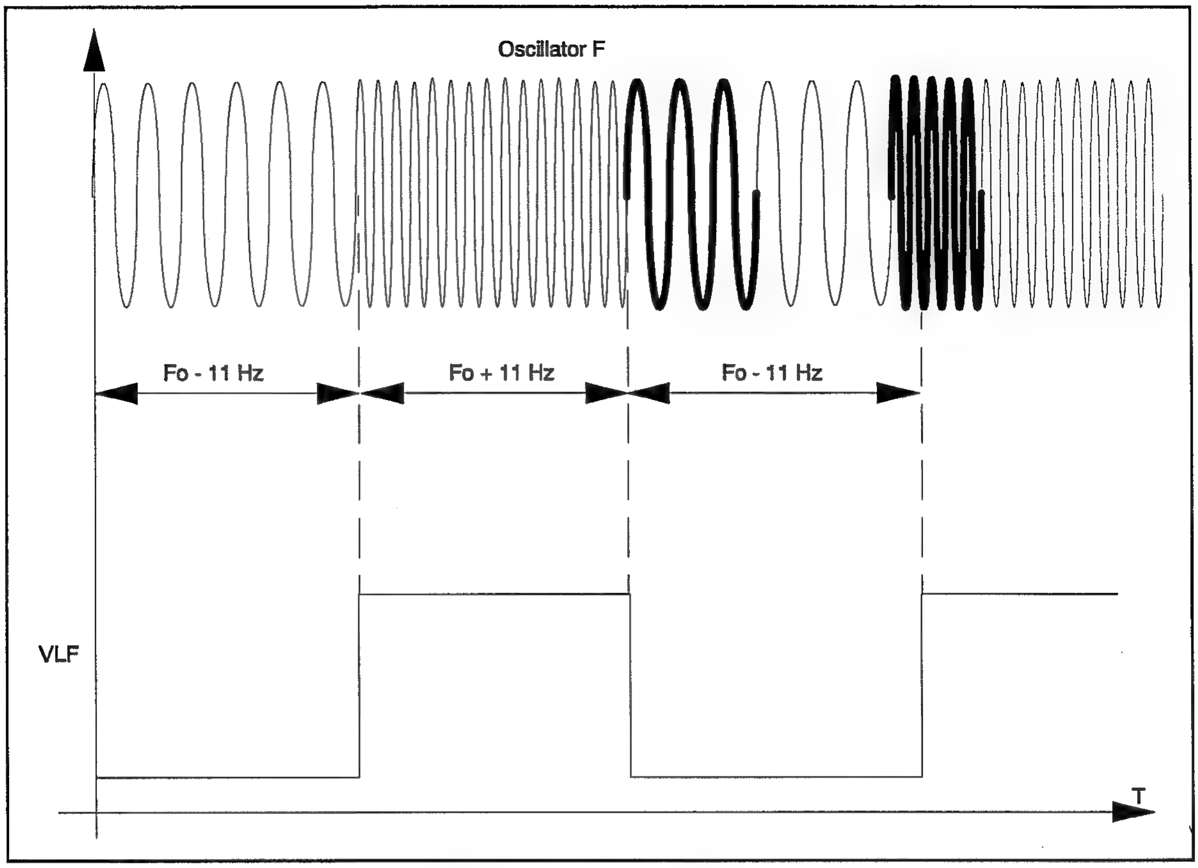


Figure 1 - UM 71 signal

4.2.2 Functional description of the transmitter (Appendix 6)

The transmitter consists of the following circuits:
- a stabilized power supply,
- an oscillator,
- an amplifier,
- a frequency divider,
- a current regulator.

4.2.2.1 Stabilized power supply

As the power supply voltage may vary between 22.5 and 28.8 V, it is stepped down to a stable value by means of Zener diodes.

This voltage, adjusted at 18 V, allows the oscillator to output a constant voltage independent from the general 24 V power supply variations.

4.2.2.2 Oscillator

The LC-type oscillator is used to generate the following frequencies:

$F_0 + \Delta F$ and $F_0 - \Delta F$

The oscillator distinctive features are:

- the tuning circuit takes account of the 18 V power supply source impedance; thus, the output level decreases as the source impedance increases.
- tuning at $F_0 + \Delta F$ is provided by two capacitors mounted in series as shown on the simplified diagram below. $F_0 - \Delta F$ is obtained by shorting capacitor Cy (fig.2).

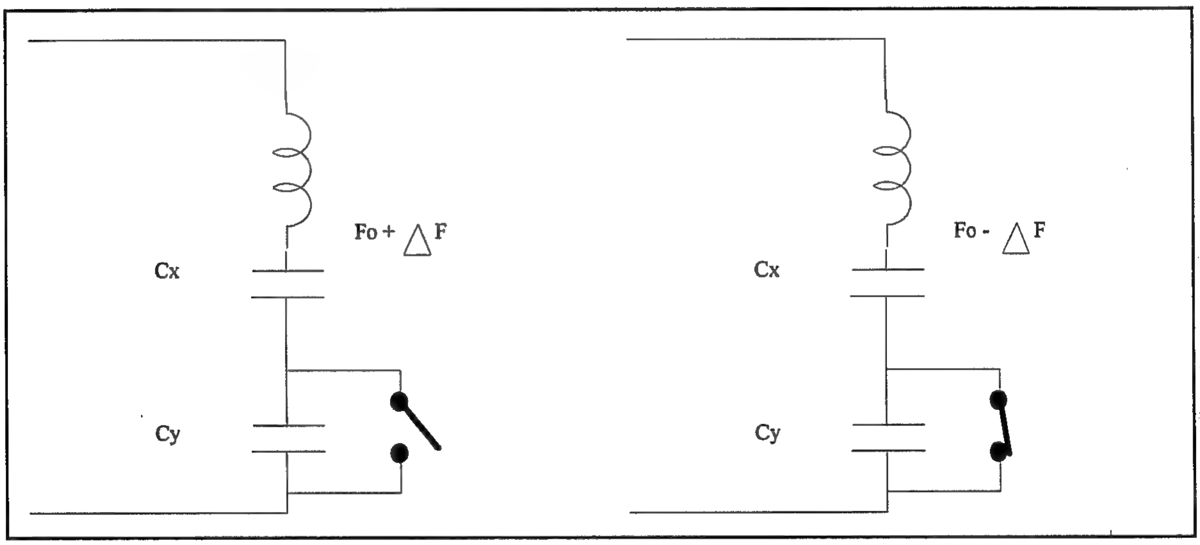


Figure 2 - oscillator

Switching between these two frequencies is drived by the divider circuit output logic state.

4.2.2.3 Frequency divider

The transmitter must be "shifted" by a basic frequency known as VLF (Very Low Frequency).

The modulating signal can be obtained after division by 128:

- of the transmitter carrier frequency Fo in "self-modulated" mode (jumper set between terminals M1 and M3),

- of a frequency external to the transmitter, for specific applications: external modulation (the modulating signal is fed across terminals A- and M3).

Division by 128 is provided by a CMOS logic circuit whose output controls shorting of capacitor Cy.

4.2.2.4 Amplifier

The signal from the oscillator is current-amplified by a setup known as "Super β" consisting of:
- an emitter follower-mounted preamplifier transistor (voltage gain = 1)
- a power stage (Darlington transistor).

This setup outputs a stable output voltage independent from the power supply voltage; the very high gain makes the oscillator insensitive to the nature of the load.

4.2.2.5 Output transformer (KEM)

The signal from the amplifier is output through a tapped transformer allowing the transmitter output level to be adjusted while providing galvanic insulation.

The available voltage is a fonction of the winding ratio (KEM) which can be varied from 0.25 to 15.75 in 0.25 steps.

The level is 46.5V approx. with a winding ratio of 3.5 under 220 ohms.

Depending on the configuration of each track circuit, a KEM winding ratio is defined at the setting stage.

4.2.2.6 Current regulator

The signal from the transmitter is output at two possible power levels:
- 10 W approx. at low power (LP)
- 20W at high power (HP) with jumpers set across terminals M2-M4-M5.

A regulating device allows the equipment to be protected in case of excessive power use (accidental output short-circuit, shunting of the track near the transmitter, etc.) by rapidly reducing the transmitter output voltage.

This device, from the image of the current picked up in the KEM transformer primary circuit, provides output voltage limiting through gradual reduction of the oscillator power supply voltage.

The transmitter operates at constant current. Thus, at LP, regulation is effective for a power supply current about 1 A, and at HP for a current of about 2A.

4.3 Receiver (Appendix 7)

4.3.1 Purpose

The receiver is used to detect the presence of a train in the associated track section. The receiver must recognize the carrier signal in quality (modulated frequency) and in quantity (level).

4.3.2 Functional break-down

The receiver consists of the following functional circuits:

- an input transformer, for adjustment of the TC (KRV),
- a bandpass carrier filter used for spurious signal suppression,
- a trigger providing the threshold function,
- a demodulator used to search for the modulation VLF signal,
- a VLF amplifier,
- a VLF rectifier and filter circuit,
- a delayed threshold oscillator, which transforms the VLF energy into a 15-kHz signal, and also provides the relay pick-up time delay function,
- an amplifier which delivers the power necessary to energize and lock the 24 V/250 ohms relay.

4.3.3 Safety criteria

Data are received "in safety" which implies the criteria defined below:

- As the receiver provides the TC shunting function, the apparent relay pallet drop-out threshold must not decrease,

- A non-modulated pure frequency signal shall not cause the relay to be locked high,

- No failure shall cause the relay to be re-energized if the relay is normally de-energized.

4.3.4 Description of functions

a) Matching (Fig.3)

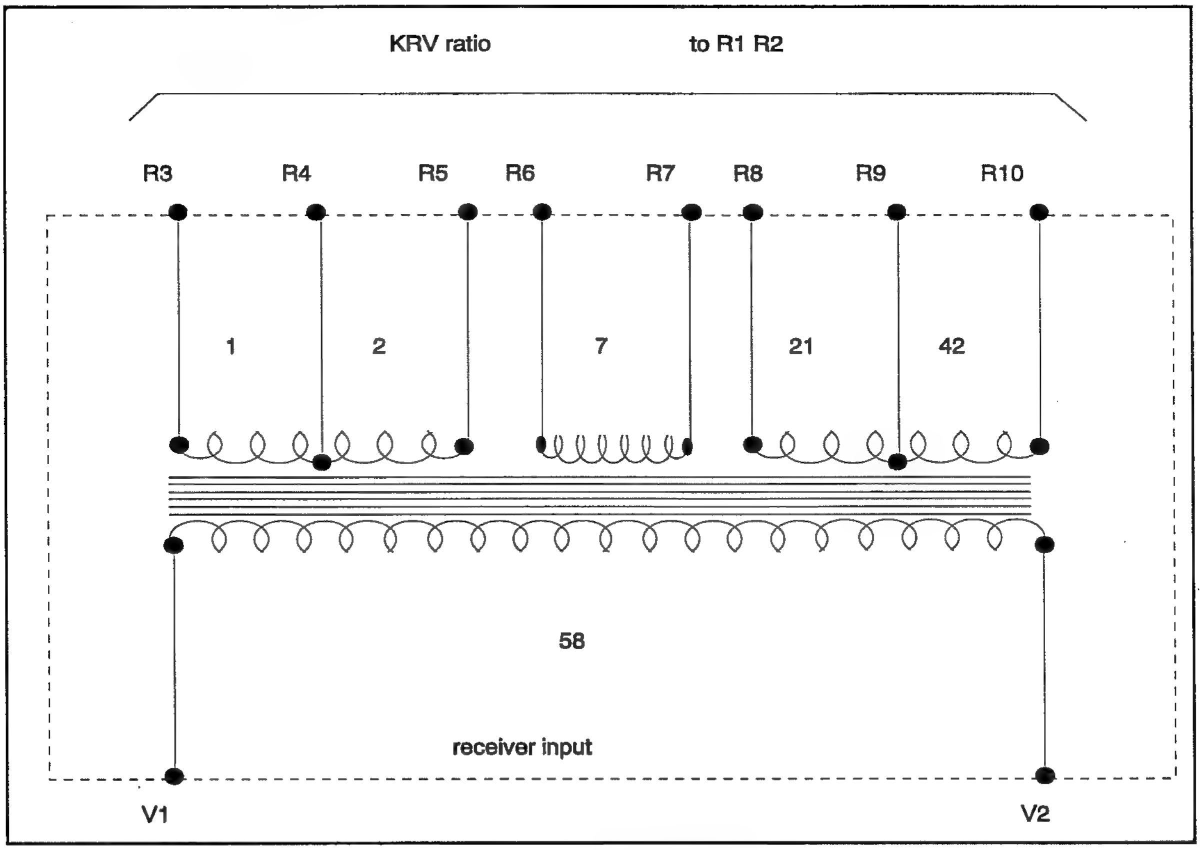


Figure 3 - Matching

The matching function is achieved by an input transformer (KRV) which provides:

- galvanic insulation between the signal from the outside of the room and the receiver internal electronics,
- a low primary impedance (V1V2) providing protection against spurious signals in the event of failure and earthing of the cable wire,
- level adjustment by means of secondary winding taps (73 possible ratios).

b) Carrier signal filtering (fig. 4)

The LC-type input filter comes in the form of a half T-cell with two branches: one series LC branch and one parallel LC branch (see diagram below).

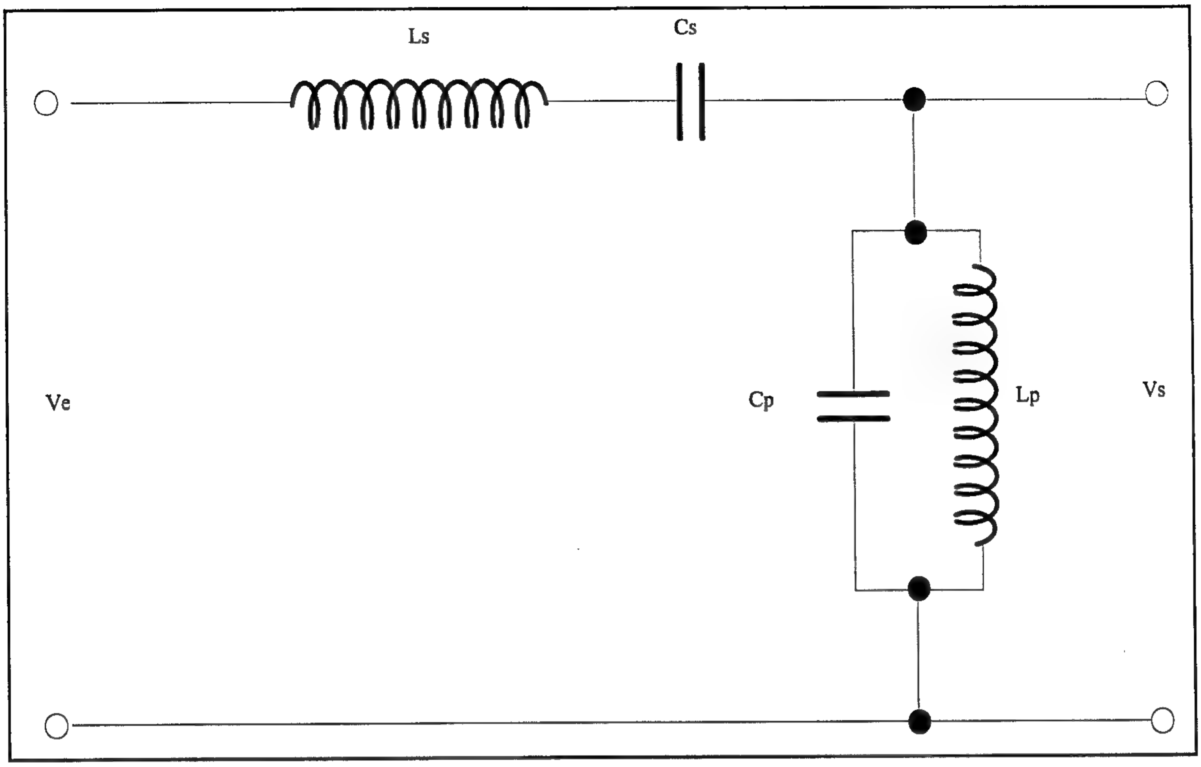


Figure 4 - filter

The input filter is an analog bandpass filter tuned at one of the four input signal Fo frequencies (1700 Hz, 2000 Hz, 2300 Hz or 2600 Hz). This filter has a pass-band of ± 40 Hz.

The filter selects the signal which corresponds to its tune frequency and thus suppresses the other signals that may be present on the track.

c) Carrier control threshold

The signal selected by the input filter is preamplified by an emitter follower-mounted transistor stage. This stage has a very high input impedance and thus prevents the trigger from loading the input filter parallel branch.

The matched signal is transmitted to a circuit consisting of two transistor stages known as a "Schmidt trigger" which determines the track relay pick-up and drop-out thresholds, independently from the power supply voltage.

d) Demodulation (fig.5)

The purpose of demodulation is to transform the frequency modulation into amplitude modulation to recover the modulation low frequency part.

The principle consists in sending the carrier signal at a constant energy level into a trap-circuit tuned at a higher frequency (Fo). The collected level is then a function of the control frequency.

The demodulator consists of a transistor stage whose collector is loaded by a R, L, C type trap-circuit. Inductance is provided by the transformer primary winding.

As the trap-circuit is tuned at frequency Fo, any frequency variation on either side of Fo results in an amplitude variation of the signal, at the shift frequency; the carrier current is constant.

The signal collected at the transformer secondary winding making up the trap consists of a HF carrier corresponding to the signal frequency and a VLF envelope representing the transmitter "shift" frequency.

A resistor, NTC (Negative Temperature Coefficient), located in the transistor base-emitter circuit, provides temperature stability for the stage.

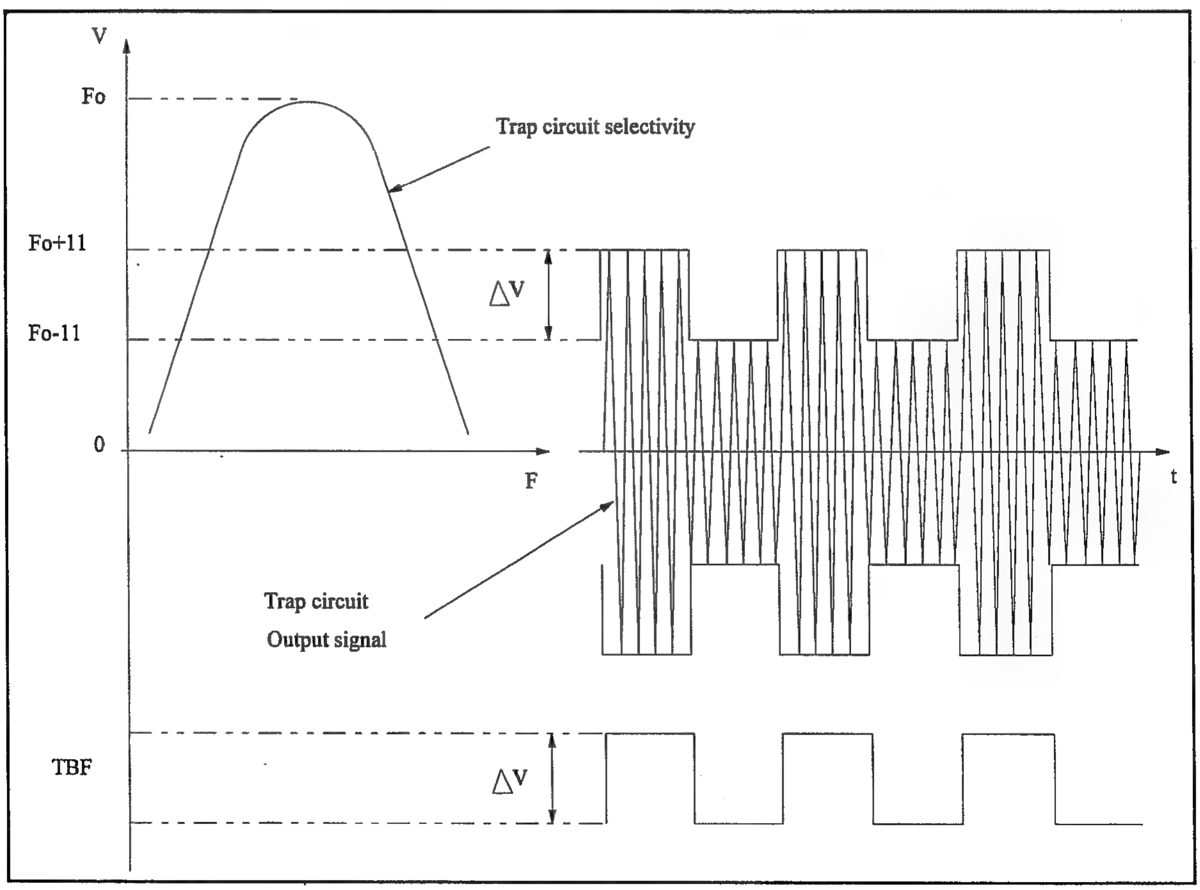


Figure 5 - Demodulation principle

e) VLF signal processing

Peak detection of the amplitude-modulated signal from the demodulator allows the VLF image signal of the signal modulating the transmission carrier frequency to be collected. It is amplified by two emitter follower-mounted transistors and by a tuned transformer.

After amplification, the VLF signal rectified by a diode bridge is filtered by a RLC-type cell.

In normal operation, the voltage at the filtering capacitor terminals is between 9 and 14 V.

f) Threshold and time-delay oscillator

The obtained filtered d.c. voltage feeds an emitter-base coupling oscillator which delivers a 15-kHz approx. sinusoidal signal.

Pick-up time-delay is provided by linking terminals C and C1 (t=0.5s) or C and C2 (t = 2 s) of the oscillator stage.

This time-delay prevents untimely pick-up of the relay in the event of a short duration shunting loss.

g) Output trigger

The sinusoidal signal from the oscillator is level-controlled by a Schmidt trigger consisting of two transistors. Operation of said Schmidt trigger is identical with that of the trigger providing carrier threshold.

The amplitude of the signal output by the oscillator depends on the d.c. power supply voltage. A 15 kHz square signal will only be sent to the output amplifier when the oscillator power supply is ≥ 8 V.

h) Relay amplifier

The purpose of the output amplifier, consisting of a transistor stage, is to deliver a power sufficient to energize the relay as soon as the signal from the 15 kHz oscillator passes the trigger threshold; hence "go - no go" operation.

After rectification and filtering, a transformer provides the energy necessary to energize a type relay 24 V/250 ohms. It also provides galvanic insulation from the outside.

A small part of the 15 kHz output signal is picked up to be fed back to the carrier signal at the input. This allows a slightly higher pre-bias of the input trigger and a 30-mV approx. hysteresis to be obtained, such that the relay drop-out occurs at an input voltage

lower than that necessary for pick-up. Thus, with a 24-V receiver power supply voltage, the input voltage VR1R2 is:

- 200 to 210 mV for relay pick-up,
- 170 to 180 mV for relay drop-out.

4.4 Electrical separation joint - ESJ (Appendix 8)

4.4.1 Composition of an ESJ

The ESJ consists of a track section limited at each end by a LC-type tuned circuit, known as the tuning unit (TU). A non-saturable track inductor, known as the ACI unit (air core inductor) or ACI (Air Cored Inductor), is located at the centre of the ESJ. Cables provide the link between the units and the track.

The ESJ contains the transmission and reception points for the track circuits located on either side of its point of installation.

4.4.2 Configuration of the ESJ

The ESJ can be configured:

4.4.2.1 with a transmitter and a receiver

- a transmitter Fx and a receiver Fy (fig.6), as generally found on end of section transmission track circuits (see diagram below).
  . The Fx track circuit transmission is done at the Fx tuning unit,
  . The Fy track circuit reception is done at the Fy tuning unit.

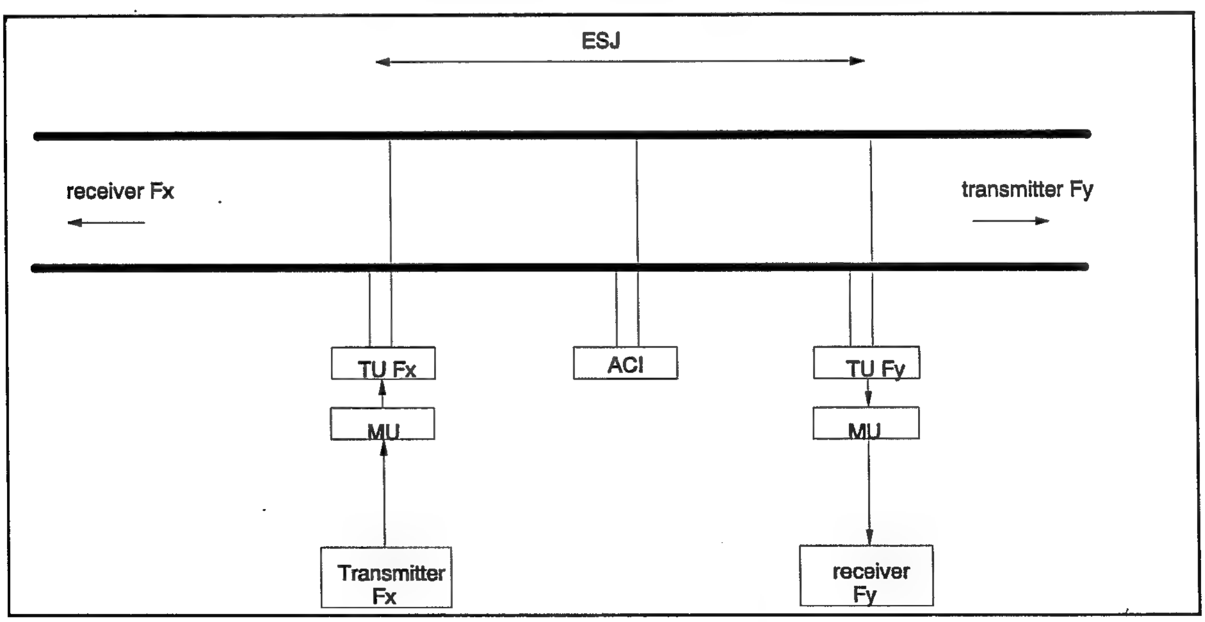


Figure 6 - config. transmitter/receiver

4.4.2.2 with two receivers

- Two receivers (fig.7), as generally found on intermediate transmission track circuits.
  . Fx and Fy Track circuits reception are done at the correspondant tuning unit.

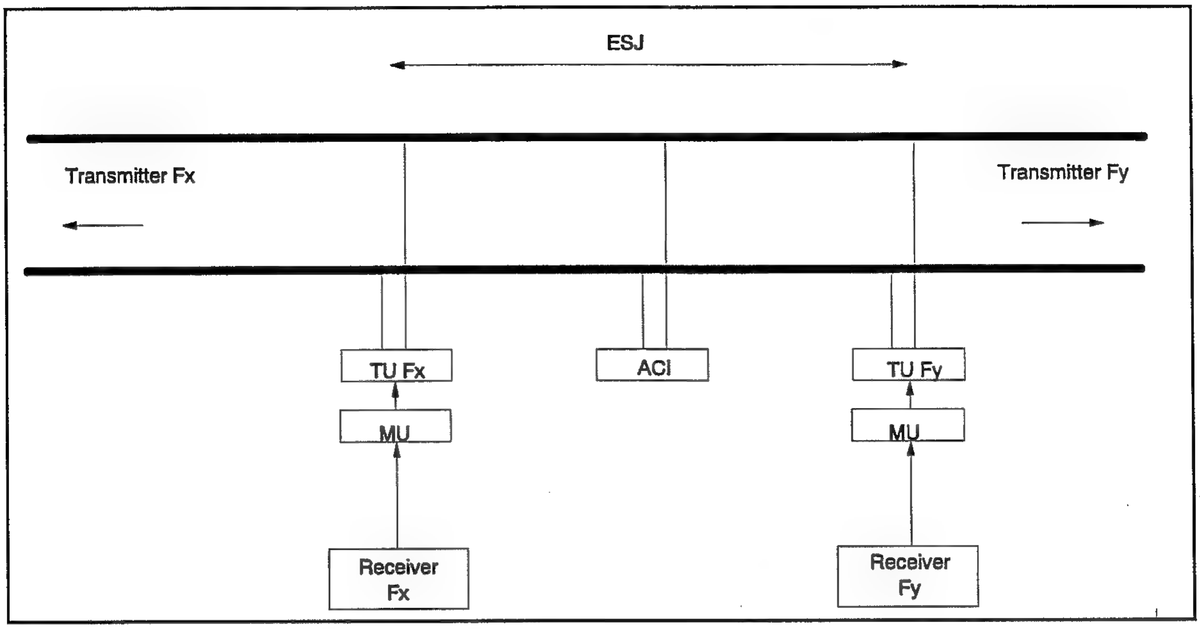


Figure 7 - config. receiver/receiver

4.4.2.3 with two transmitters (not recommended)

- **Using Two transmitters in the same ESJ is possible but no recommended (fig.8). Limited the transmitters power is required no to sature the tuning unit with high current.**

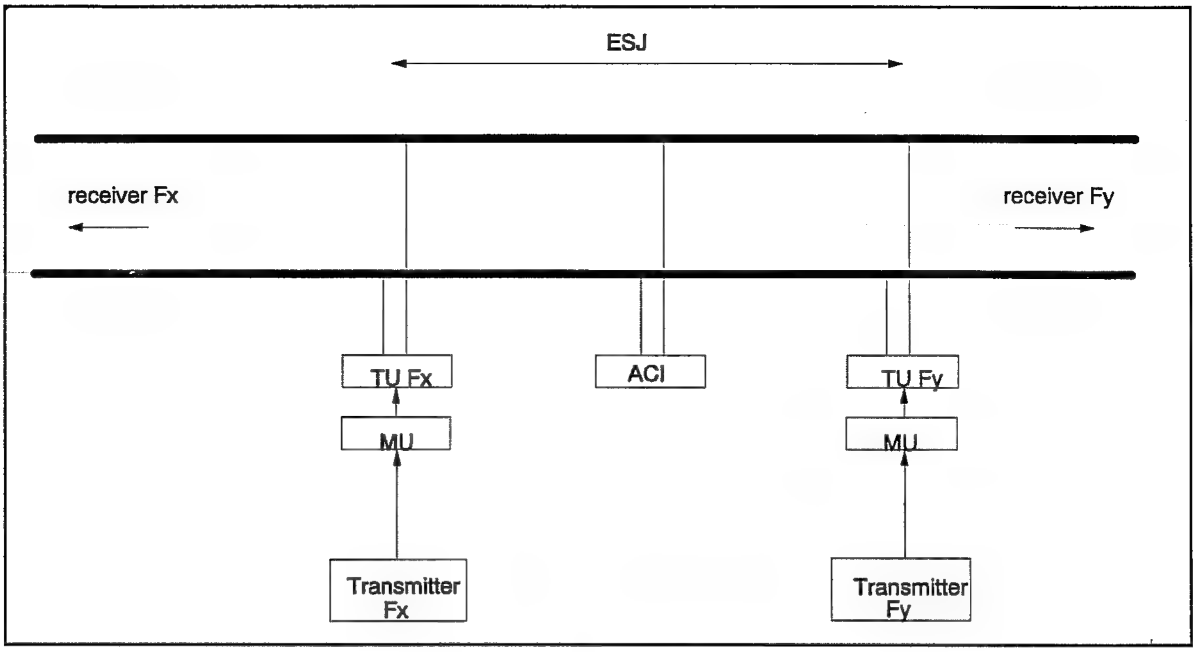


Figure 8 - config. transmitter/transmitter

4.4.2.4 with transmitter or receiver located in interface with areas non mounted with track circuits (fig.9).

- The extreme tuning unit could be replaced with a short circuit cable. The ACI is not required in this configuration.

  The ESJ length is shorter.

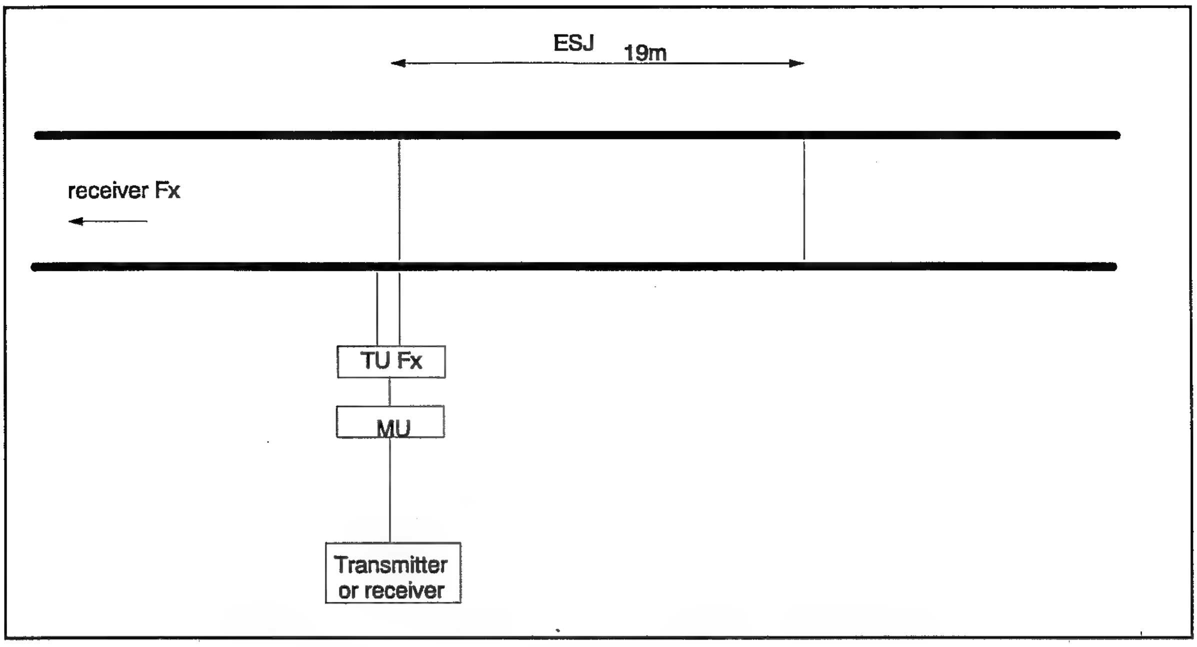


Figure 9 - interface with area without track circuits

4.4.3 Principle of operation of the ESJ

Implementation of track circuits requires reliable separation of audio frequencies on all contiguous track circuits (common to the same ESJ). This can be achieved either conventionally through the use of insulated rail joints which break the rail electrical continuity, or through electrical separation joints which do not require rail discontinuity.

Electrically, the ESJ consists of two nested trap-circuits, tuned at the frequencies of the two adjacent track circuits, respectively.

Their purpose is:

- to have at the track circuit end a relatively high terminal impedance at the TC frequency, in order to promote signal transmission. The impedance of an ESJ is in the order of 1,3 to 2 ohms depending on frequency.

- to prevent the track circuit frequency from propagating beyond the ESJ extreme limits (longitudinal cross-talk).

These functions are provided through the implementation of tuned circuits (tuning units) at the ESJ ends.

There are two types of tuning units:

1) <u>Tuning unit F1 (V1 or V2)</u> (fig.10)

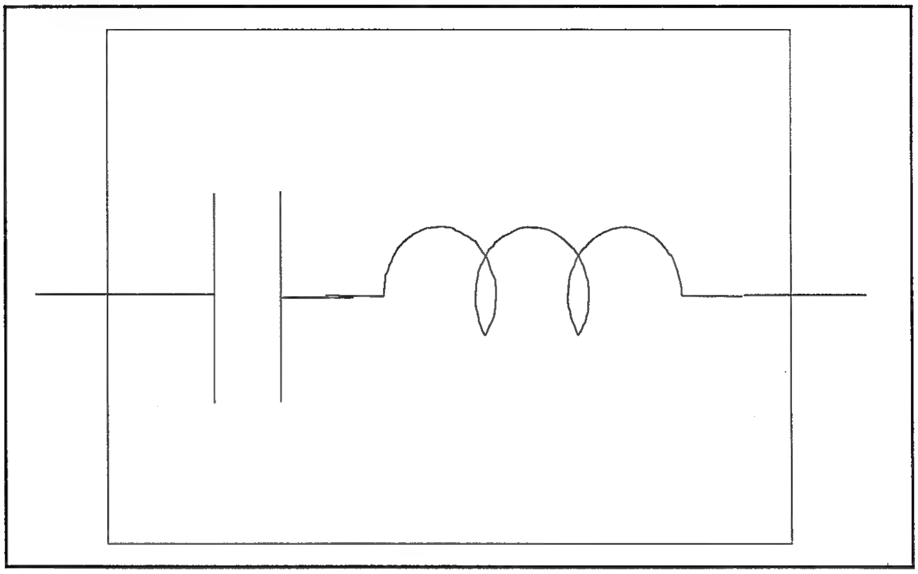


Figure 10 - Tuning unit F1

This consists of a LC series circuit tuned at a frequency close to F2. Its characteristics are:

- capacitive impedance at frequency F1,
- low capacitive impedance at frequency F2.

2) <u>Tuning unit F2 (V1 or V2)</u> (fig.11)

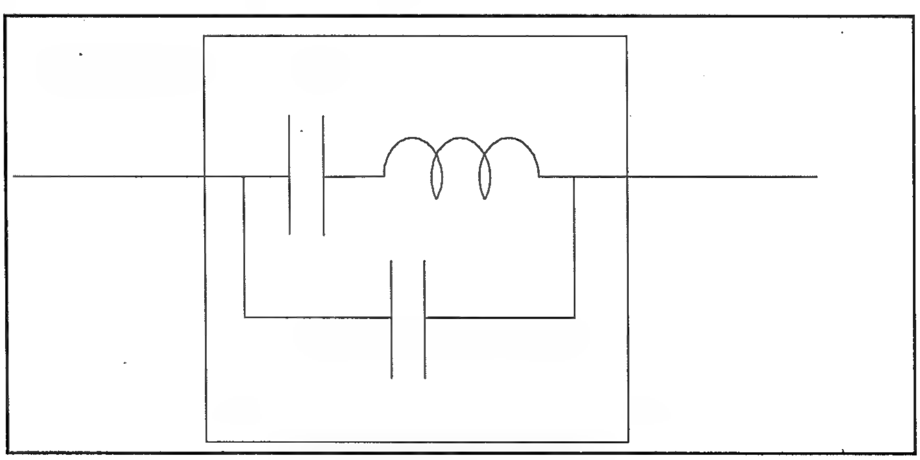


Figure 11 - Tuning unit F2

This consists of a LC series circuit, tuned at a frequency close to F1, mounted in parallel with a high value capacitor.

Its characteristics are:

- low capacitive impedance at frequency F1, with the parallel capacitor shorted by the series branch tuned at F1,

- capacitive impedance at F2, resulting from the tuning of the three components. As frequency F2 is higher than frequency F1, the inductive series tuning is masked by the parallel capacitor.

There is one tuning unit per track circuit frequency.

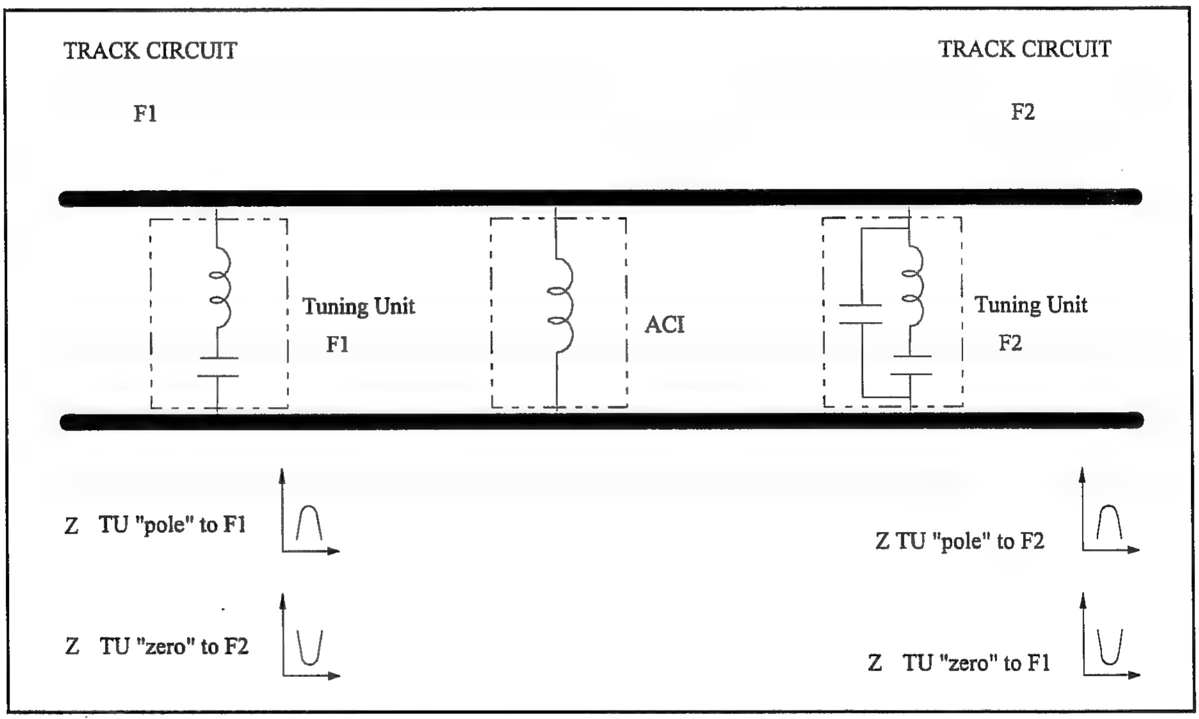


Figure 12 - electrical analogy

For track 1 frequency pair :
- a V1F1 TU exhibiting a "zero" at 2300 Hz and a "pole" at 1700 Hz.
- a V1F2 TU exhibiting a "zero" at 1700 Hz and a "pole" at 2300 Hz.

For track 2 frequency pair :
- a V2F1 TU exhibiting a "zero" at 2600 Hz and a "pole" at 2000 Hz.
- a V2F2 TU exhibiting a "zero" at 2000 Hz and a "pole" at 2600 Hz.

The "zero" defines the frequency at which the TU impedance is minimum.

The "pole" defines the frequency at which the TU impedance is high.

The Air core inductor ACI, located at the centre of the ESJ allows :
- re-equalization of the traction current returns between rails,
- enhancement of the ESJ Quality-value, thus increasing the TC terminal impedances.

The two rails, in track circuit operation, make up the transmission line. This is defined by primary parameters:
- R : resistance per unit length of the rails (ohm/km, longitudinal impedance),
- L : inductance per unit length of the rails (H/km, longitudinal impedance),
- G : conductance per unit length of the track (S/km, transverse impedance),
- C : capacity per unit length of the track (F/km, transverse impedance).

The track can therefore be represented by the following circuit diagram:

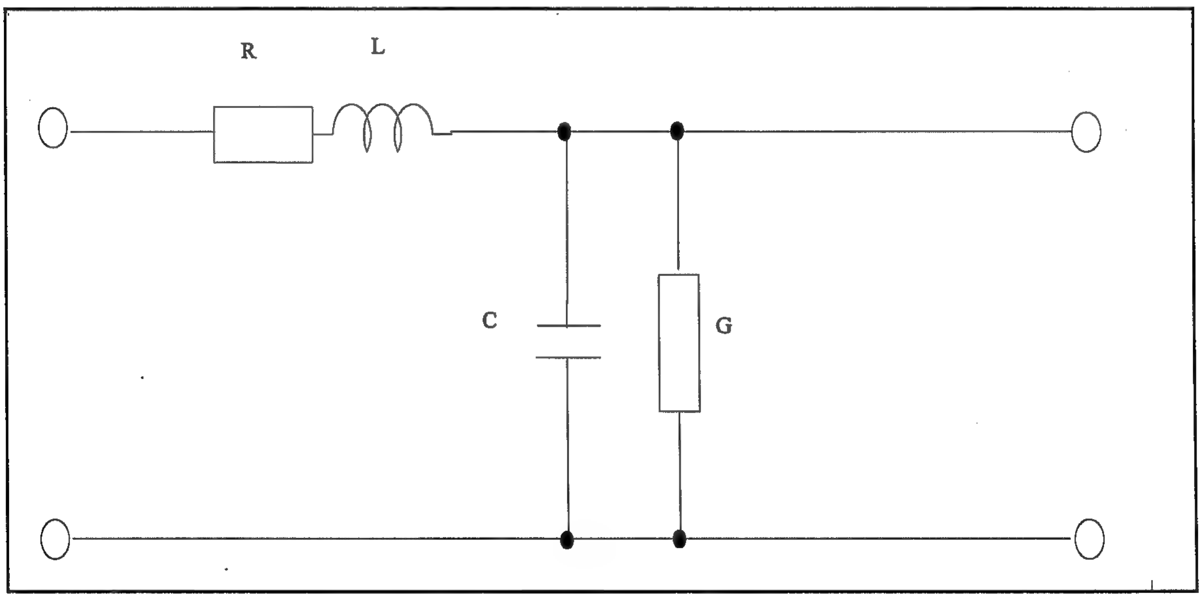
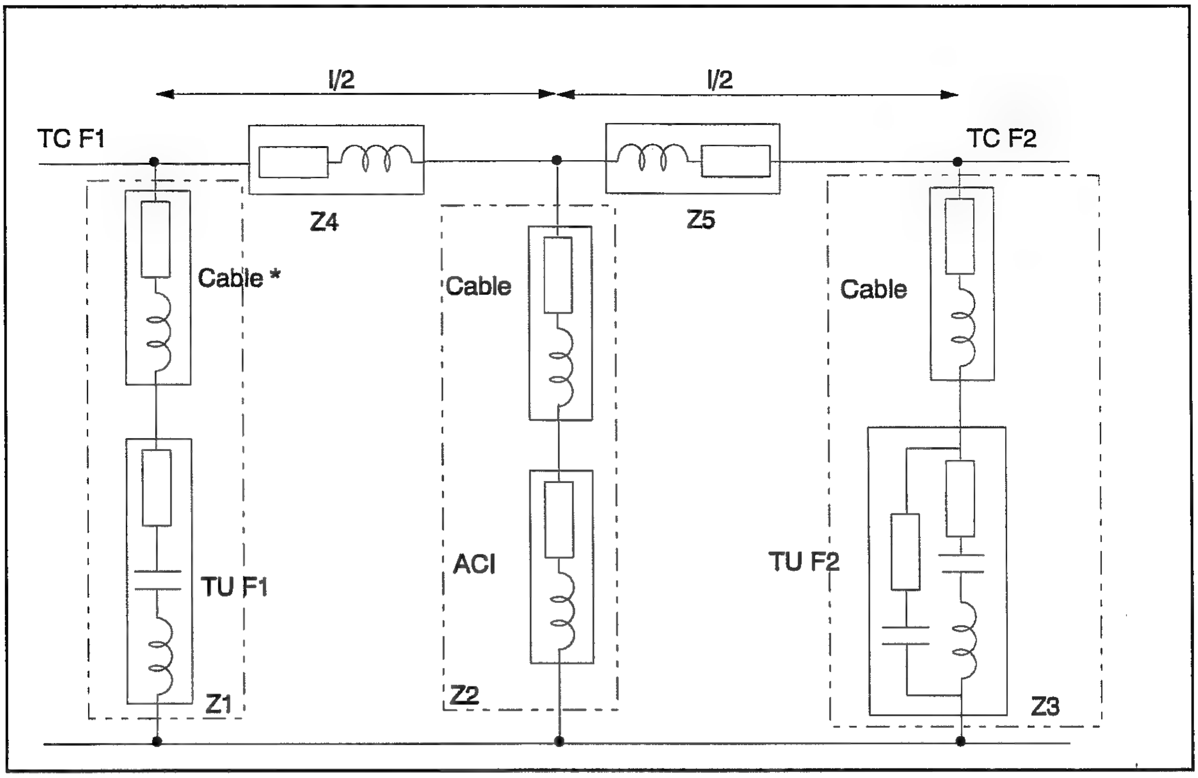


Figure 13

On the very short track section represented by the ESJ, parameters G and C can be deemed negligible; only R and L are taken into account for calculation of the ESJ.

Figure 14 shows the circuit diagram of the impedances involved in an ESJ.



* connecting cables between the units and the track

Figure 14 - ESJ circuit diagram

The example below (fig.15) shows the electrical analogy of the ESJ at frequency F1.

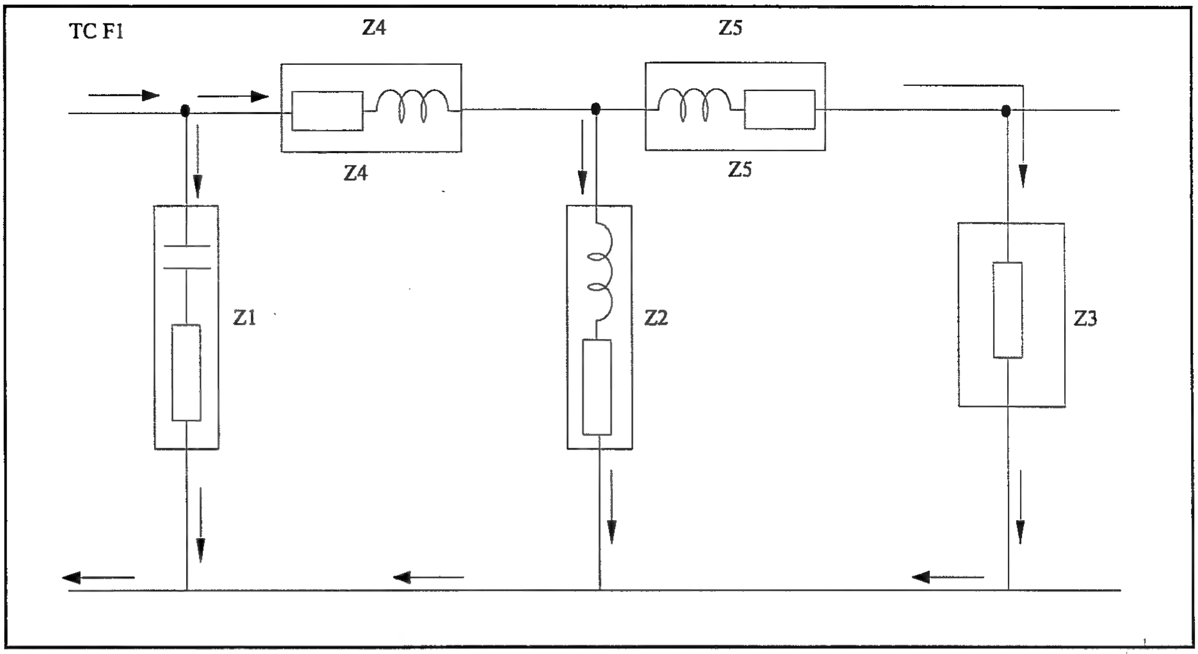


Figure 15 - electrical analogy at the frequency F1

At frequency F1:

- impedance Z1 is capacitive. It represents the "pole" impedance of TU F1 with the track connecting cables.

$$Z1 = Z\ \text{cable} + Z\ \text{TU F1 "pole"}$$

- impedance Z2 is inductive. It includes the impedances of the ACI and connecting cables.

$$Z2 = Z\ \text{ACI} + Z\ \text{cables}$$

- Impedance Z3, very low, takes account of the TU F2 "zero" impedance as well as the track connecting cables.

$$Z3 = Z\ \text{TU F2 "zero"} + Z\ \text{cables}$$

<u>**Important**</u>

The "zero" impedance of TU F2, slightly capacitive, compensates the track connection cables inductance. Thus, as seen from the track, Z3 represents an actual impedance close to a short-circuit (a few milliohms only). This very low impedance depends on the length and the positionning of the cables.

- Impedances Z4 and Z5 represent the track impedance making up a half-ESJ.

$$Z4 = Z5 = R \times l/2 + J\,(L \times l/2 \times \omega)$$

As seen from TU F1, Z2, Z3, Z4 and Z5 represent the following equivalent inductive impedance:

$$Z_{eq} = \frac{(Z3 + Z5) \times Z2}{Z2 + Z3 + Z5} + Z4$$

This impedance, coupled in parallel to capacitive impedance Z1, makes a trap circuit which determines the impedance of the ESJ at frequency F1

$$Z_{JES} = \frac{Z_{eq} \times Z1}{Z_{eq} + Z1}$$

- The short circuit presented by Z3 prohibits the propagation of frequency F1 beyond the limits of the TC.

4.4.4 **Electrical analogy** (fig.16)

The following figure presents in electrical analogy the "ESJ" principle at the adjacents frequencies.

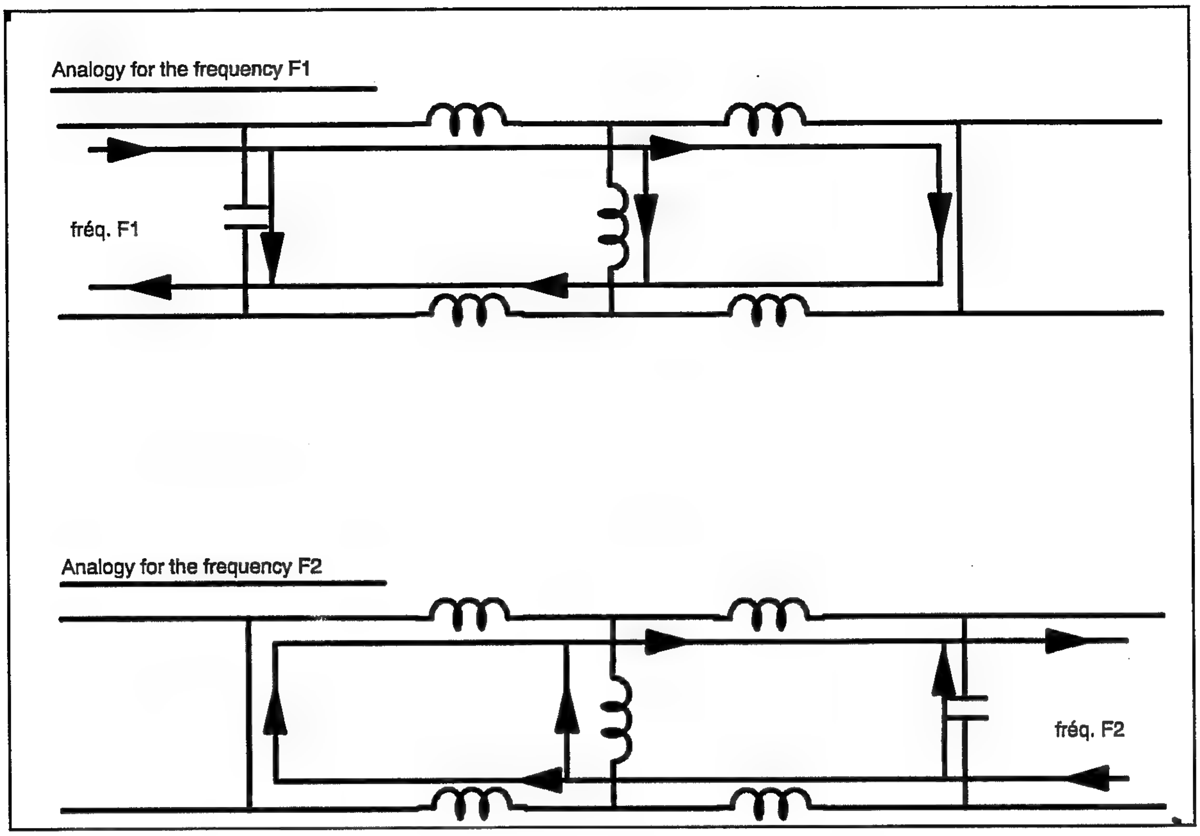


Figure 16 - electrical analogy at frequencies F1 and F2

4.5 Termination on insulated rail joints (IRJ)

4.5.1 Configuration (appendix 9)

A termination on insulated rail joints, set up in transmission or reception includes:
- an air core inductor ACI ,
- a Tuning Unit TU
- a Matching Unit MU,
- connecting cables between the track and the ACI,
- connecting cable between the ACI and the TU
- a connecting cable between the TU and the MU

4.5.2 Operating principle

In a termination on insulated rail joints setup, the track circuit terminal impedance (transmission or reception), is defined by the parallel setup of the ACI and the TU. The TU capacitive impedance tunes up with the ACI inductive impedance thus forming a trap-circuit (Fig. 17).

The assembly presents an impedance of approximately 3 to 4 ohms according to frequency

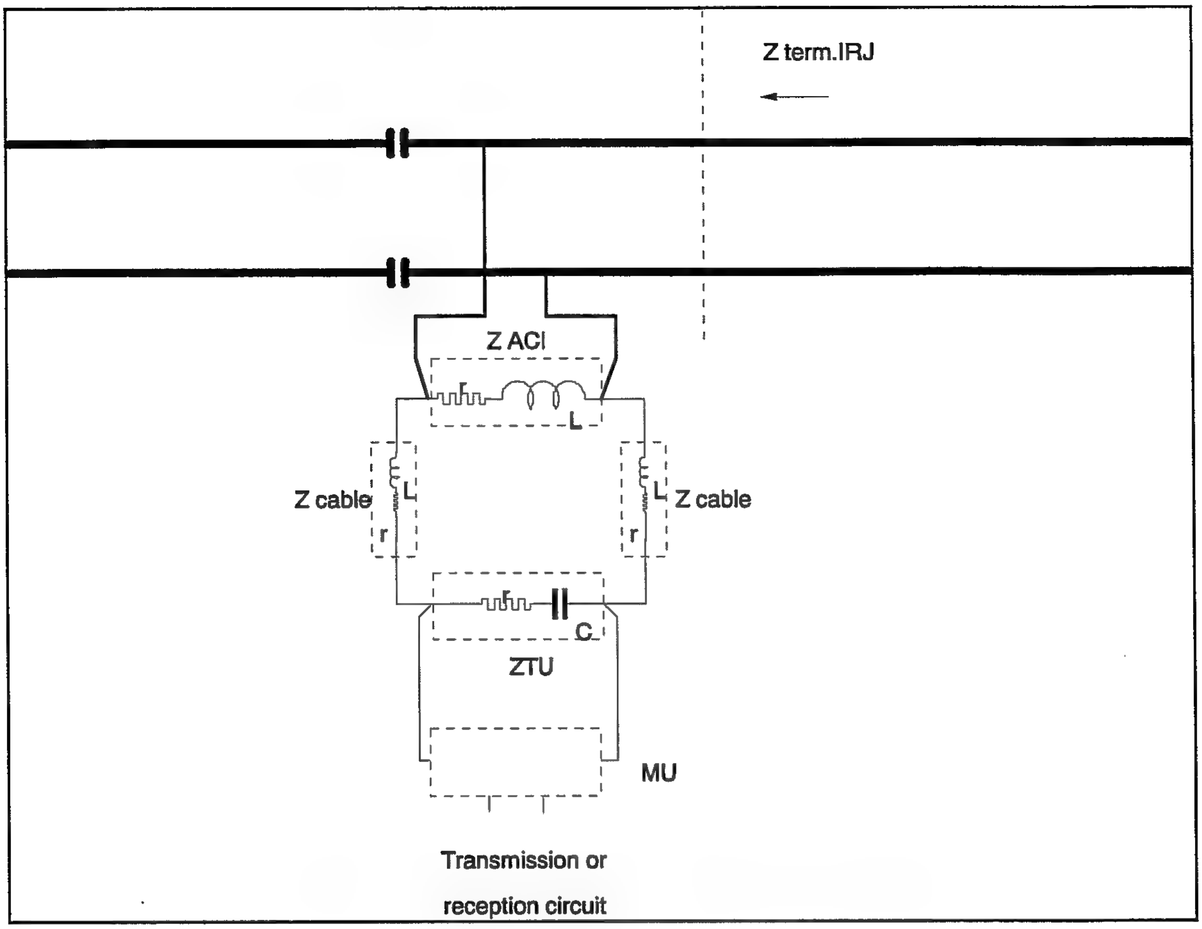


Figure 17 - Termination on insulated rail joints

$$\text{Zterm IRJ} = \frac{\text{ZACI} \times (\text{ZTU} + 2\text{xZcable})}{\text{ZACI} + \text{ZTU} + 2\text{xZcable}}$$

A TU exists per frequency,
The ACI is common for all frequencies.

The length, nature and positioning of the connecting cables between the TU and the ACI must be strictly observed. Their impedance significantly impacts the tuning of the assembly.

4.6 Intermediate transmission (IT)

4.6.1 Configuration (appendix 10)

A intermediate transmission includes :

- an air core inductor ACI,
- a tuning unit TU,
- a matching unit MU,
- connecting cables between the track and the ACI,
- connecting cables between the ACI and theTU,
- connecting cables between the MU and the TU

4.6.2 Operating principle

Intermediate transmission uses the same principle as transmission on insulated rail joints as described in section 4.5.

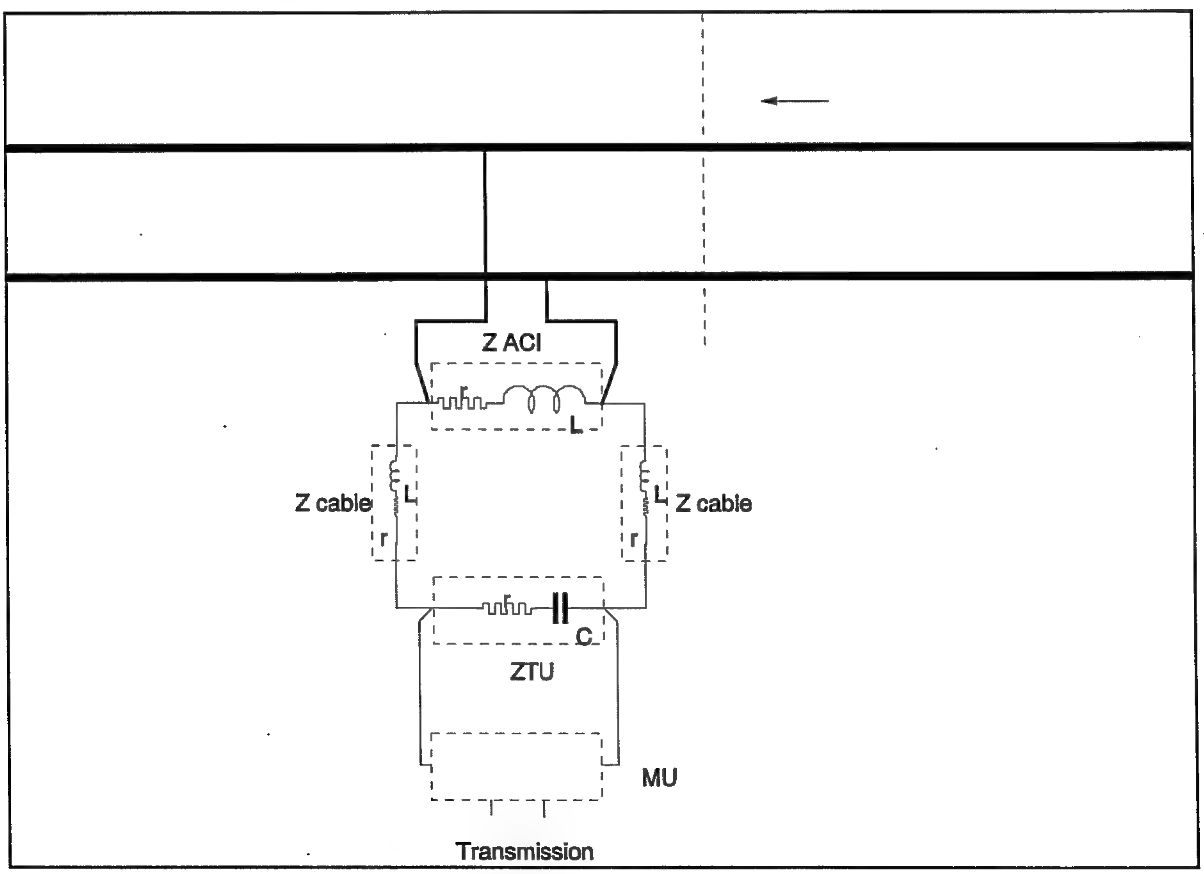


Figure 17a - Intermediate Transmission

The assembly presents an impedance of approximately 3 to 4 ohms according to frequency.

The length, nature and positioning of the connecting cables between the TU and the ACI must be strictly observed. Their impedance significantly impacts the tuning of the assembly.

4.7 Matching and linking of field/equipment room and land side cabinet equipment

4.7.1 Principle of operation (fig.18)

4.7.1.1 Adaptation of the transmission line

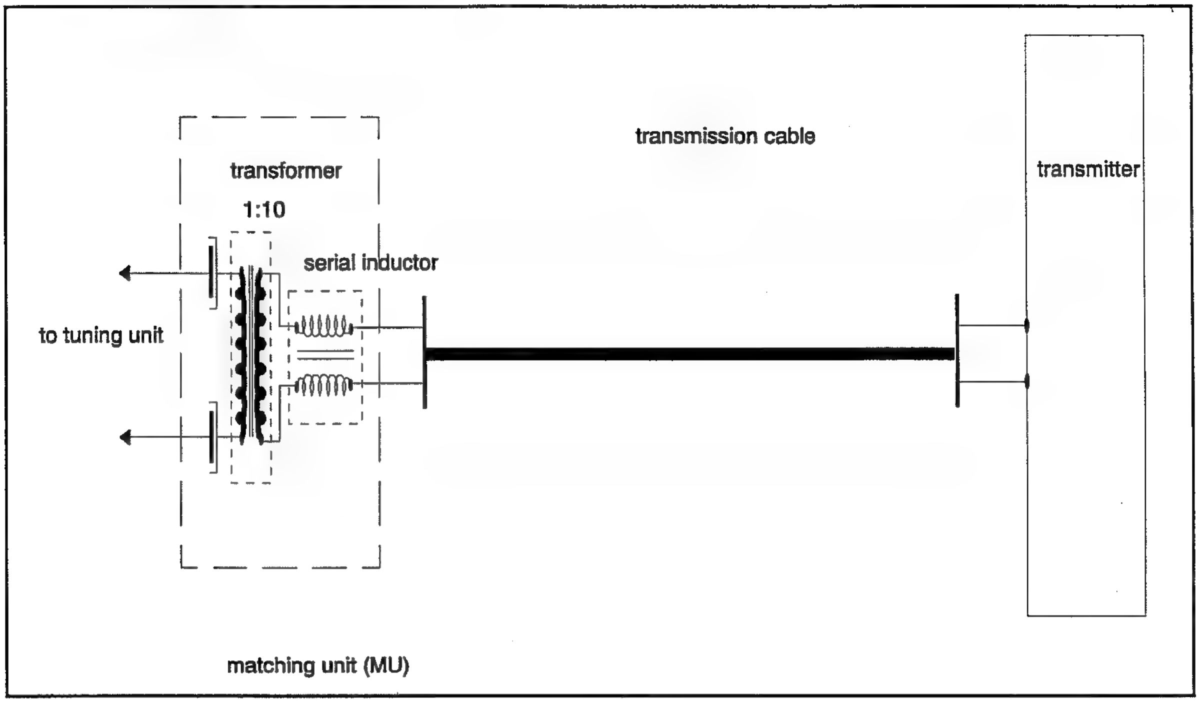


Figure 18

The MU consists of:
- a tapped transformer
- a series inductor,
- two capacitors connected head to tail,
- a series resistor (short circuited in this utilisation).

Coupling of a MU is according to the type of termination.

- In transmission on ESJ, IRJ or IT, the transformer is coupled to a ratio of 10 (Fig.18).

  The series inductor inserted in the transmission circuit promotes shunting within the track circuit and allows the short-circuit returned from the track at train crossing to be masked at transmitter output.

4.7.1.2 Adaptation of the reception line (fig.19)

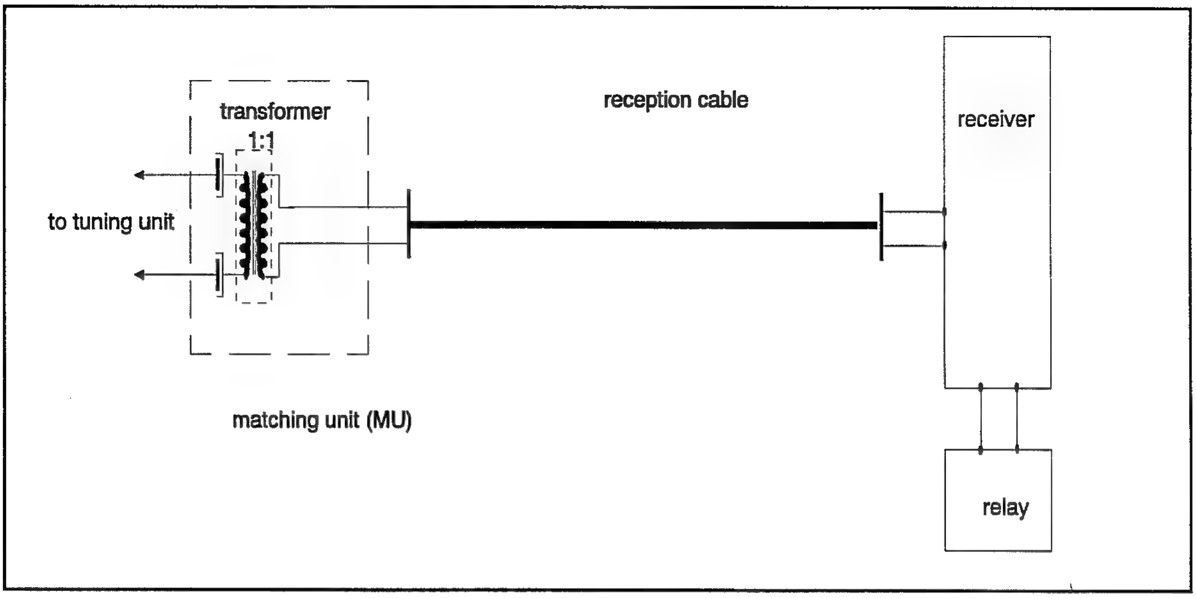


Figure 19 - reception line

The ratio 1:1 is used in this case. The transformer is used as a galvanic insulation between the track and the receiver and the series resistor is also short-circuited..

4.8 Intermediate data collector - IDC (Appendix 11)

4.8.1 Information point IP

4.8.1.1 configuration

an information point includes:
- a receiver UM71 with an associated relay
- a matching unit (MU)
- connection cables between the rail and the MU,
- cable between the MU and the receiver.

4.8.1.2 Principle (fig.20)

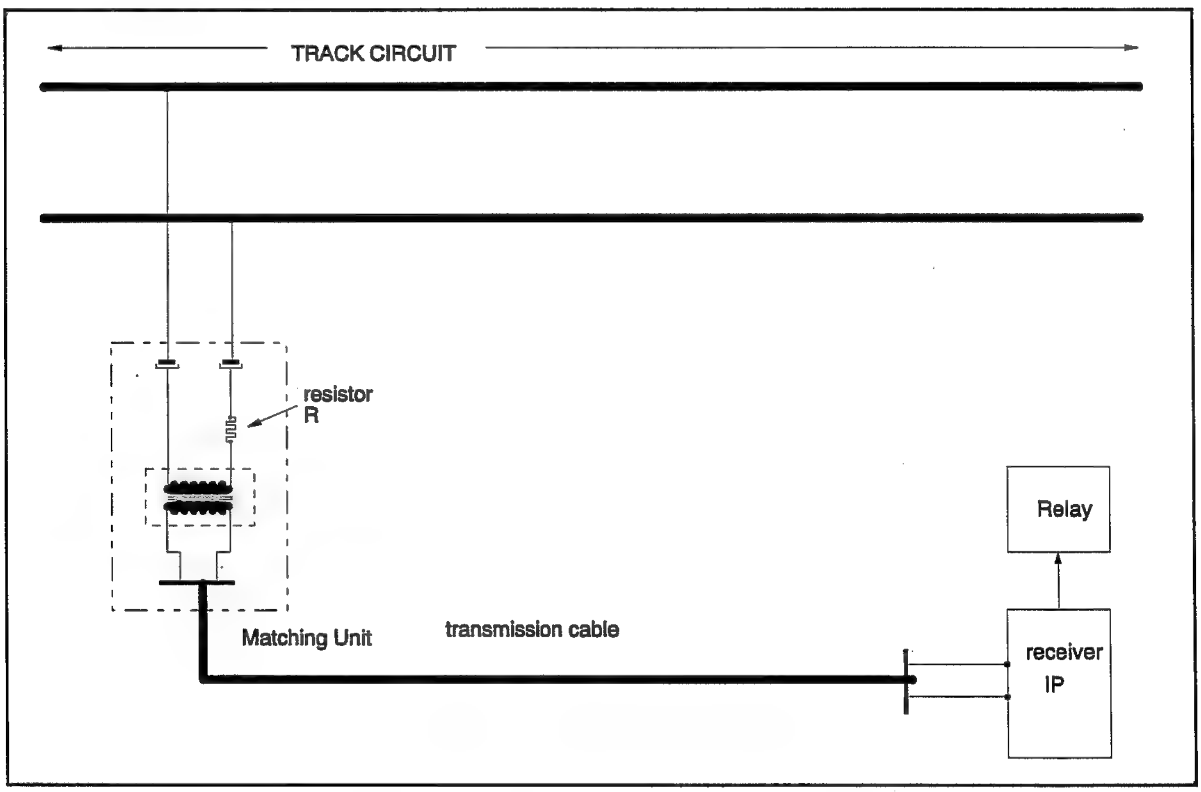


Figure 20 - Information point

The voltage signal measured between the two rails - anywhere in the track circuit - is transmit to receiver associated with a relay. The maximum reception line is set at 1000m with the cable specified at chapter 6.

adaptation MU

Adjustment of the transformation ratio 1 to 1.5 is done in accordance with line length and the location of the IP in track circuit.

The 22 ohms resistance in use in this configuration is not short circuited. It increases the IP impedance to avoid loading the support track circuit.

4.8.1.3 **Incertain status area** (Fig . 21)

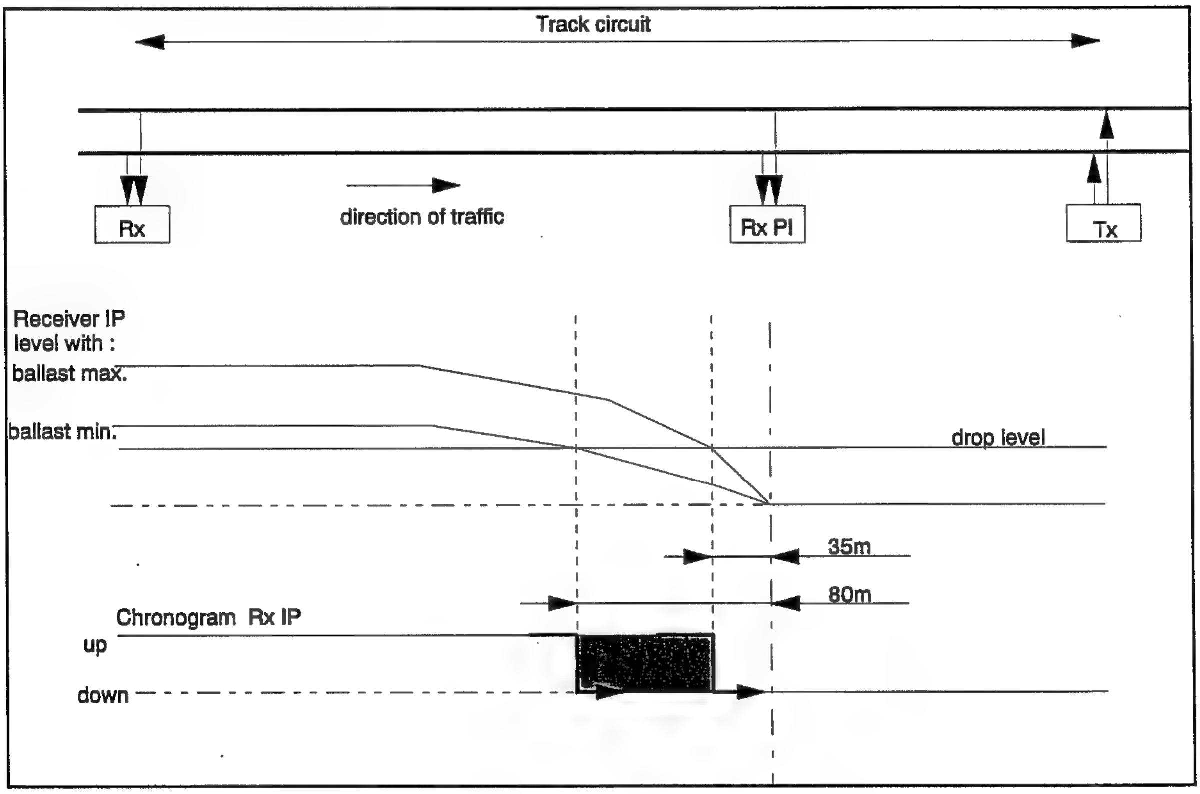


Figure 21 - incertain status area

The IP change of status cannot be precisely define. This status varies according to the ballast resistance value. The incertain status area rank from 35 to 80m from the IP location.

4.8.1.4 **Shunt efficiency**

The theoritical shunt 0.1 ohm value is guarantee between the transmitter and the IP.

4.8.1.5 Installation rules

The IP cannot be used in compensed track.

Only one IP can be installed in a end feed transmission track circuit.

Two IP can be installed in an intermediate transmission track circuit.

There is not track circuit limitation length when using IP.

4.8.2 Pin Point Detector PPD

4.8.2.1 configuration

A PPD includes:
- a pin point detector unit PPDU,
- a receiver and a relay,
- cables between PPD and receiver,
- a boosting Unit if the main Track Circuit length is over than 200m.
- a Matching Unit (MU)

4.8.2.2 principle (fig.22)

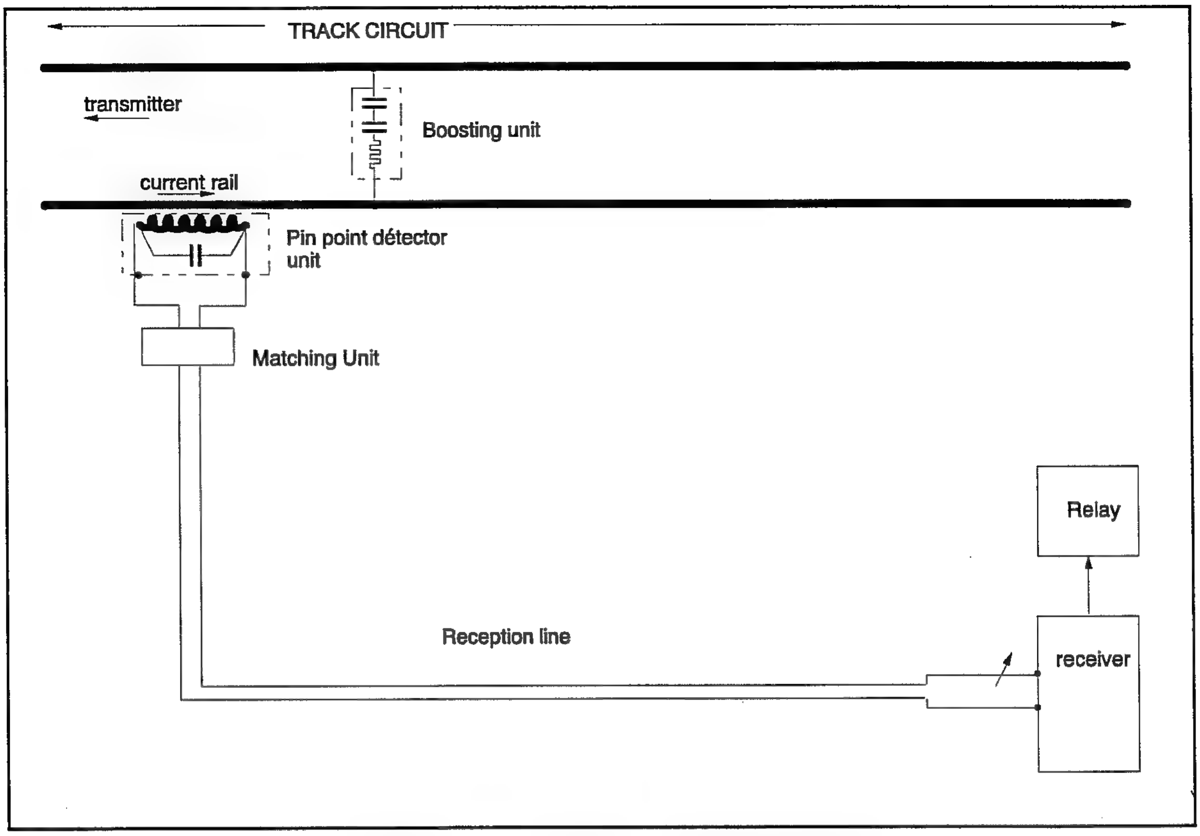


Figure 22 - principle Pin Point Detector

The signalisation current in the rail is measured with a PPD Unit. The PPD unit is composed with an "inductive device" tuned to Track Circuit frequency. The PPD Unit is located next to the rail. The rail current is transmitted per induction to the PPD unit. The voltage measured at the PPD Unit supplies through an adjustment resistor the receiver input.

The PPD Unit output depends directly on the amount of the track circuit current flowing in the rails. The use is strictly limited to the following minimum current values

- 570mA for a 1700Hz track circuit
- 520mA for a 2000Hz track circuit
- 485mA for a 2300Hz track circuit
- 470mA for a 2600Hz track circuit

A Boosting Unit device can increase the current value in the rail in order to respect the minimum value described above. The Boosting Unit is composed of a 10 ohms/10W resistance, protected from DC current by two electrolytic capacitors (≥ 100µF) head to tail mounted. It is installed between rails.

4.8.2.3 Shunt efficiency (fig.23)

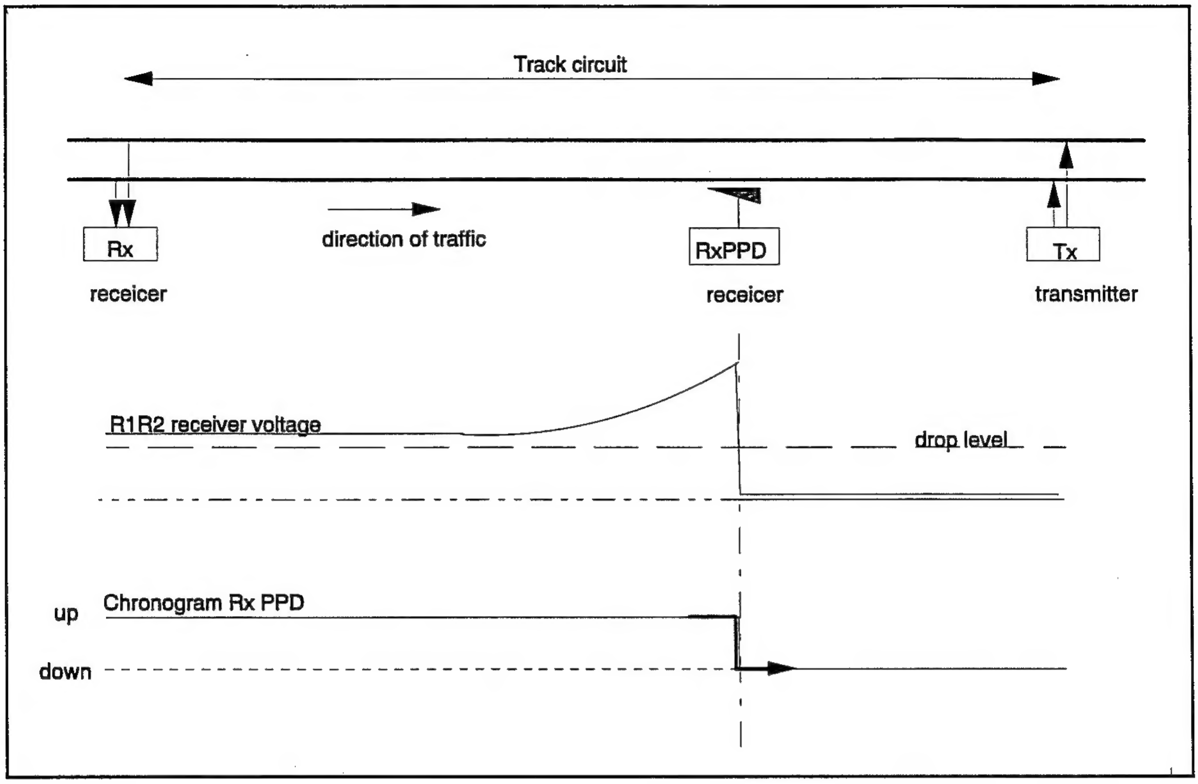


Figure 23 - Shunt efficiency

The theoritical shunt value is guarantee between the transmitter and the PPD following the under conditions:

The Track Circuit section located between the receiver and the PPD shall be free of rolling stock and no be shunted.
For those reasons it is forbidden to run several trains simultaneously on the same track circuit.

4.8.2.4 Installation rules

The IP cannot be used in compensed track.

The PPD shall be installed at less than 100m from the transmitter.

The maximum receiver cable length is set at 100m

The maximum main Track Circuit UM71 length is set at 250m; this length can be

extend to 400m by adding a "Boosting Unit" device.

The boosting unit device shall be located at 1m from the PPD Unit, on the track circuit receiver side.

There is one PPD per frequency. The information delivered by the PPD is transmitted to a standard receiver through a Matching Unit. The adjustment depends on the length of the track circuit, the length of the linking cable between the Matching Unit and the receiver; it is made at the secondary of the MU.

Note:

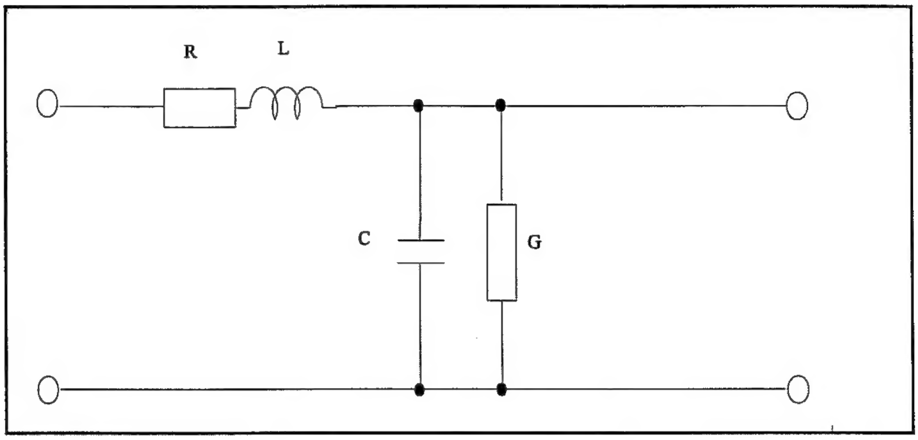
When the PPD is very close by the receiver, the adjustment can be made in a simpler manner, by replacing the Matching Unit with an adjustable resistor (1000Ω): see appendix 24.

The use of a MU is better for noise immunity. The voltage on the R1R2 inputs of the receiver should be ≥270mv.

4.9 Track compensation

4.9.1 Principle

The track can be represented by the following equivalent electrical circuit:



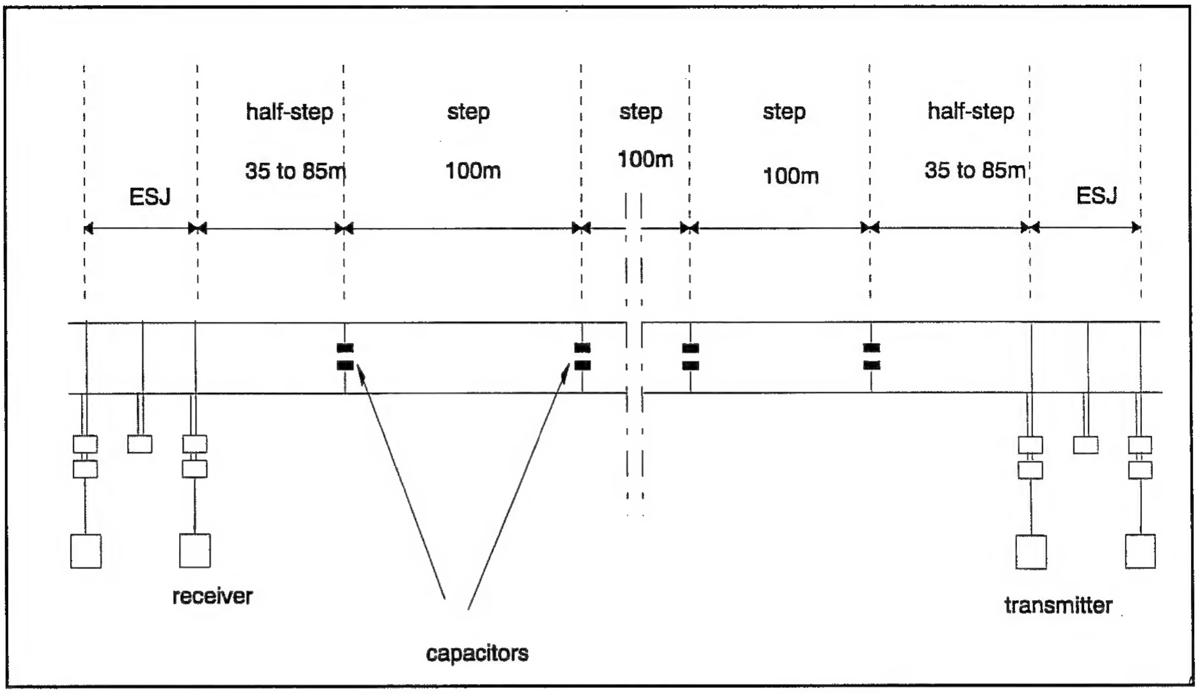
G = 1/Rb is due to the losses caused by the ballast. The resistance Rb (Ohm.km) can vary from 1.5 Ohms to infinity.

The capacitor C (a few µF/km) depends of the type of track but is insignificant for the UM71 TC frequencies.

The longitudinal impedance is mainly inductive (about 15 Ohms/km for a R resistance of about 1,50 Ohm). The longitudinal impedance limits the signal propagation very quickly.

This inductive impedance can be greatly reduced by artificially increasing the capacitance between the 2 rails of the track (per km) by adding capacitors carefully spaced out between the rails ; this method constitutes track compensation and allows:
- longer track circuits,
- higher short circuit currents in the case of track-machine transmission.

track compensed principle



The length for which compensation is used depends of the track characteristics:
- track impedance,
- ballast resistance,
- rail gauge.

with a ballast resistance of 1.5 ohm.km, compensation is necessary when the TCs is longer than:
- 600m, for an end of section transmission.

For shorter lengths of TCs, compensation is not used.

The maximum length of a compensated TC is:
- 1100 m, for an end of section transmission.

The condensers capacities are: 22 and 33 µf.

The choice of capacitors is a function of the TC frequency in order to obtain optimum transmission matching.